Biological Assessment Report

Little Osage River
Vernon County, Missouri

October 2008 – April 2010

Prepared for:

Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch

Prepared by:

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Division of Environmental Quality
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1.0 Introduction

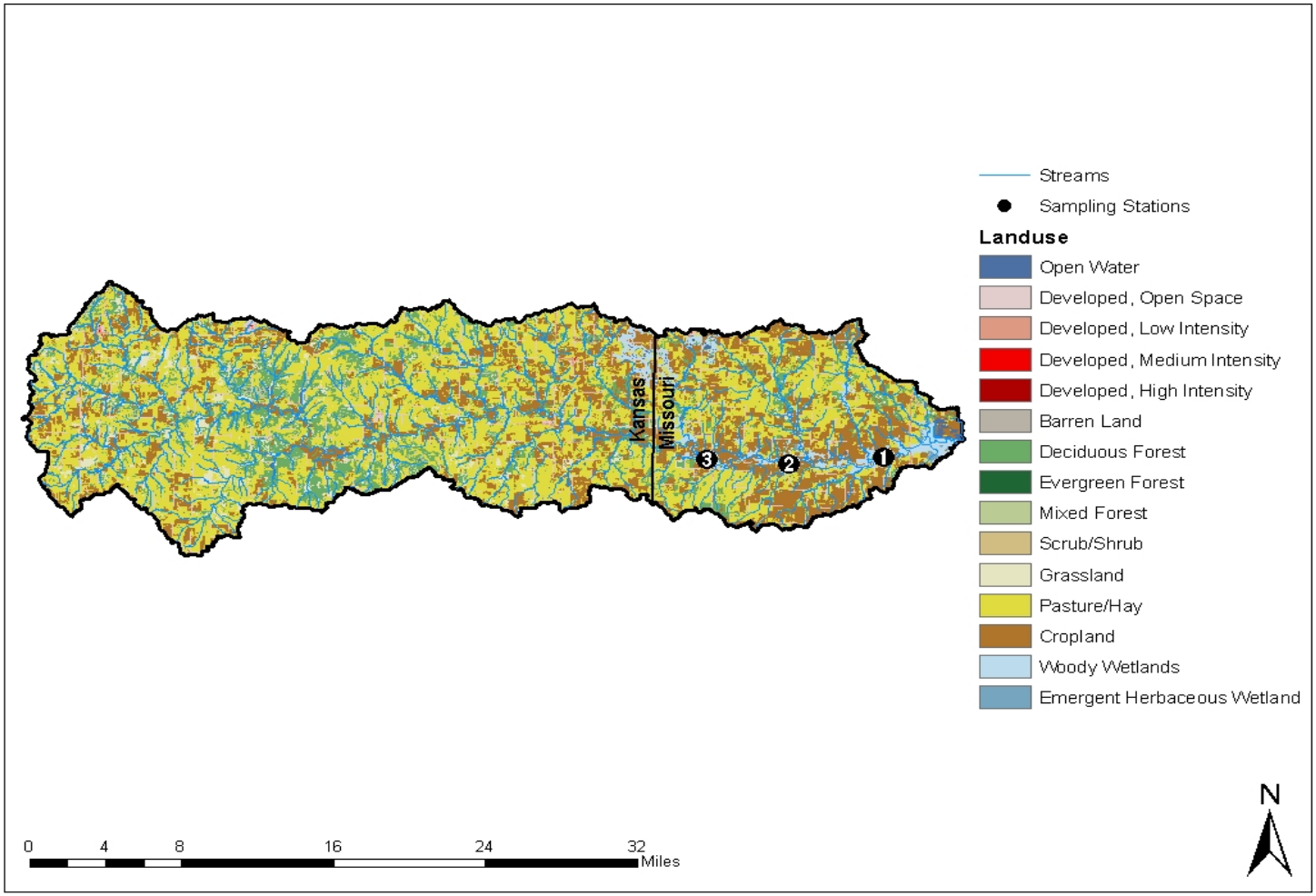
At the request of the Water Protection Program (**WPP**), the Environmental Services Program (**ESP**) Water Quality Monitoring Section (**WQMS**) conducted a biological assessment of the Little Osage River. The Little Osage River watershed originates in eastern Allen and Anderson counties in Kansas and flows east through Bourbon County, Kansas and Vernon County, Missouri to its confluence with the Marais Des Cygnes River near Papinville, Missouri. The Little Osage River is in the Central Plains/Osage/South Grand Ecological Drainage Unit (**EDU**) and is listed in the water quality standards as a class "C" stream for its first 23.6 miles (WBID 3652) in Missouri and class "P" for 27.4 miles (WBID 1310) to its confluence with the Marais Des Cygnes River. Designated uses for the Little Osage River are "warm water aquatic life protection, human health/fish consumption, livestock and wildlife watering, and class B whole body contact" (MDNR 2010a). The class C segment of the Little Osage River in Missouri was included on the 2008 303(d) list for low dissolved oxygen and bacteria.

1.1 Study Area/Justification

The Little Osage River watershed is primarily rural and most of the land use is made up of cropland and grassland (Figure 1). There are no discharging point sources in Missouri, but there are two minor wastewater treatment facilities (**WWTF**) in Kansas near the state line that discharge into the Little Osage River watershed. The Fulton, Kansas WWTF, which discharges into the Little Osage River, has a design discharge of 0.02 million gallons per day (**MGD**). The other point source is from the Prescott, Kansas WWTF, which discharges into a tributary of the Little Osage River and has a design discharge of 0.04 MGD. The relative lack of point sources in the Little Osage River watershed and the high percentage of grassland and cropland indicate that non-point source pollution is potentially a greater source of stress than point source.

A previous biological assessment study on the Little Osage River at one station located just north of the town of Stotesbury found that dissolved oxygen levels were below the 5 mg/L water quality standard in late July of 2006 (MDNR 2007). A datalogger that recorded dissolved oxygen and water temperature every 15 minutes was deployed at the station from July 25-27, 2006. All of the dissolved oxygen values collected by the datalogger were below the 5 mg/L water quality standard. *In situ* dissolved oxygen measurements were also collected on the same date as macroinvertebrate samples. These measurements showed that dissolved oxygen was below the 5 mg/L water quality standard on October 10, 2006 (2.78 mg/L), but not during the spring on March 16, 2007 (6.8 mg/L). The results of the Macroinvertebrate Stream Condition Index (**MSCI**) scores from the biological assessment study showed inconclusive results. During the fall 2006 sampling season, the Little Osage River sampling station had the highest possible MSCI score of 20, which indicated the macroinvertebrate community was not impaired. But during the spring 2007 sampling season, the station only scored a 10, which indicated impairment. There are two possible explanations for the difference in the MSCI scores between the two sampling seasons.

Figure 1
Land Use of the Little Osage River Watershed Upstream of the Confluence with Marmaton River



The first is that the Little Osage River experienced a high flow event (200-300 cubic feet per second discharge) about a month prior to the spring sampling season that most likely scoured the stream channel and reduced the available macroinvertebrate community. The second explanation is the higher water levels during spring 2007 made the stream much more difficult to sample and get a representative sample of the stream reach since only part of the stream was wadeable compared to the fall 2006 sampling season. The sampling station was barely wadeable during the fall sampling season and a canoe had to be used to collect the sample during the spring sampling season.

1.2 Objectives

The goals of this study were to get a better understanding of the extent of the low dissolved oxygen levels during low flow and to assess the condition of the macroinvertebrate community. The original plan for this study was to collect bioassessment samples at three sampling stations during the fall 2008 and spring 2009 sampling seasons. But because of high water levels during the spring 2009 sampling season, samples were collected during the fall 2008 and spring 2010 sampling seasons. In addition to the bioassessment sampling, dataloggers were deployed by U.S. EPA, Region 7 at three locations near the bioassessment sampling stations to determine dissolved oxygen levels in the Little Osage River. The dissolved oxygen data collected by the U.S. EPA were compared to data collected by MDNR Water Quality Monitoring Section staff at multiple stations on Little Drywood Creek (ERC 2010), a biological criteria reference stream in the Central Plains/Osage/South Grand EDU.

1.3 Tasks

1) Conduct a biological assessment of the macroinvertebrate community on the Little Osage River at three stations during the fall 2008 and spring 2010 sampling seasons.

2) Conduct a stream habitat assessment at the sampling stations to ensure comparability of aquatic habitats.

1.4 Null Hypotheses

1) The macroinvertebrate community will not differ between longitudinally separate reaches of the Little Osage River.

2) The macroinvertebrate community in the Little Osage River will not differ from the glide/pool biological criteria for the Central Plains/Osage/South Grand EDU.

3) The stream habitat assessment scores will not differ between longitudinally separate reaches of the Little Osage River.

4) The stream habitat assessment scores in the Little Osage River will not differ from Little Drywood Creek, a biological criteria reference stream in the Central Plains/ Osage/South Grand EDU.

5) Physicochemical water quality in the Little Osage River will meet the Water Quality Standards (**WQS**) of Missouri (MDNR 2010a).

6) Physicochemical water quality will not differ between longitudinally separate reaches of the Little Osage River.

2.0 Methods

Carl Wakefield, Randy Sarver, Brandy Bergthold, and Brian Nodine of the Water Quality Monitoring Section, Missouri Department of Natural Resources, Division of Environmental Quality, Environmental Services Program conducted this study.

2.1 Study Timing

Macroinvertebrate and discrete water quality samples were collected at the sampling stations once each during the fall 2008 and spring 2010 sampling seasons. A stream habitat assessment was conducted at the sampling stations during the fall 2008 sampling season. Fall 2008 sampling was conducted on October 7-8, 2008 and spring 2010 sampling was conducted on April 15, 2010.

2.2 Station Descriptions

A total of three Little Osage River bioassessment stations and three U.S. EPA, Region 7 dissolved oxygen datalogger stations were sampled for this study. See Figure 2 for the locations of the sampling stations.

2.2.1 MDNR Bioassessment Sampling Stations

Little Osage River #1 – Vernon County: Legal description was SE1/4 Sec. 13, T37N, R32W. Geographic coordinates were UTM zone 15, 377387 Easting, 4205384 Northing. Station located west of Vernon County Road 1325 at MDC Balltown Access.

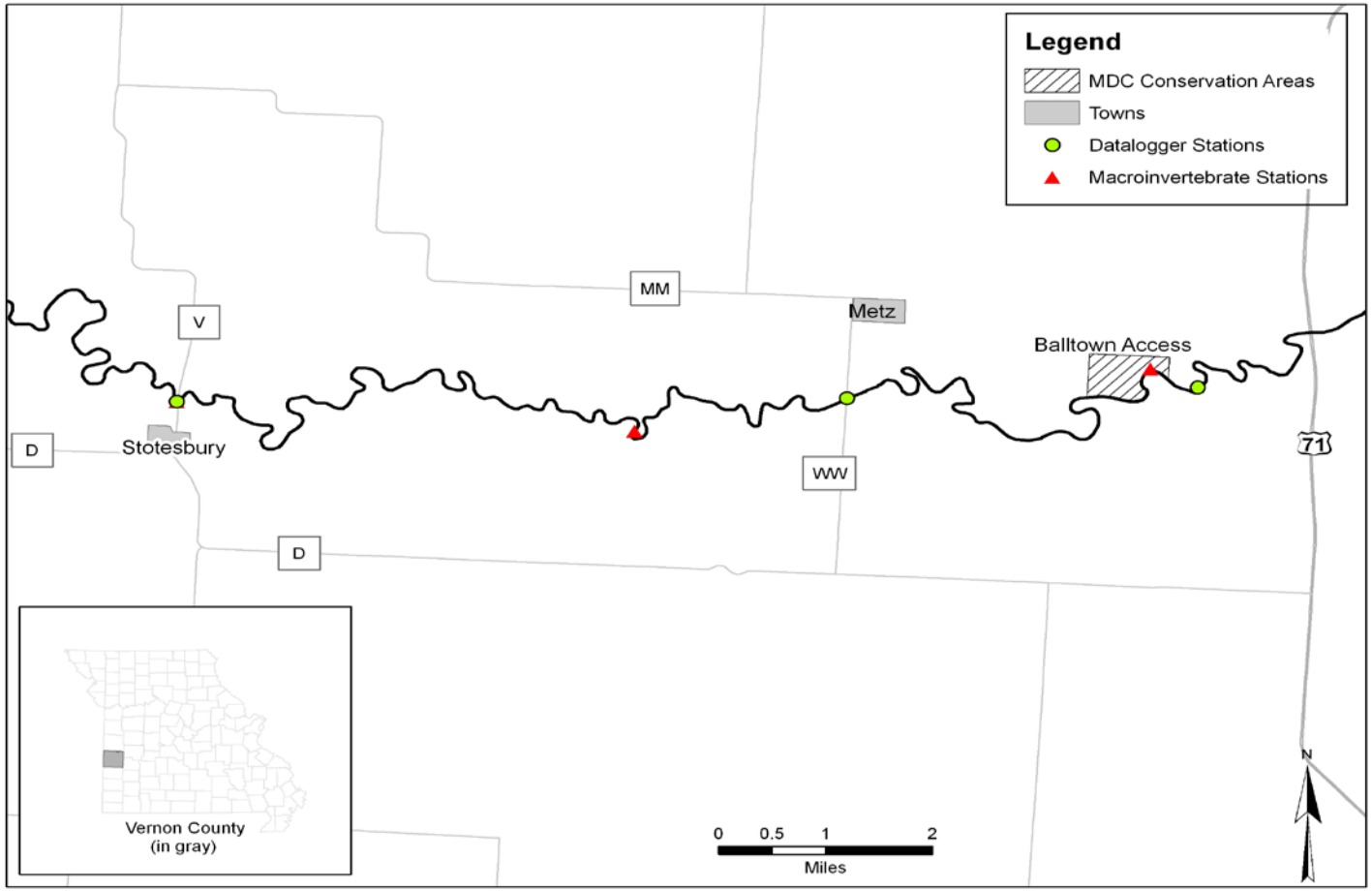
Little Osage River #2 – Vernon County: Legal description was SW1/4 Sec. 20, T37N, R32W. Geographic coordinates were UTM zone 15, 369618 Easting, 4204300 Northing. Station located north of Vernon County Road 800 on private property.

Little Osage River #3 – Vernon County: Legal description was NE1/4 Sec. 21, T37N, R33W. Geographic coordinates were UTM zone 15, 362725 Easting, 4204817 Northing. Station located upstream of Missouri Highway V.

2.2.2 U.S. EPA, Region 7 Dissolved Oxygen Datalogger Sampling Stations

Little Osage River #1 – Vernon County: Legal description was SW1/4 Sec. 18, T37N, R31W. Geographic coordinates were UTM zone 15, 378107 Easting, 4205065 Northing. Station located at Vernon County Road 1325 crossing.

Figure 2
Map of the Little Osage River and Sampling Stations



Little Osage River #2 – Vernon County: Legal description was NE1/4 Sec. 21, T37N, R32W. Geographic coordinates were UTM zone 15, 372824 Easting, 4204872 Northing. Station located at Missouri Highway WW.

Little Osage River #3 – Vernon County: Legal description was NE1/4 Sec. 21, T37N, R33W. Geographic coordinates were UTM zone 15, 362725 Easting, 4204817 Northing. Station located upstream of Missouri Highway V.

2.3 MoRap Aquatic Ecological Classification

The aquatic ecological classification developed by the Missouri Resource Assessment Partnership (**MoRAP**) is a classification system that divides the aquatic resources of Missouri into distinct regions. It has seven levels of classification starting at large regions and then dividing them into smaller sub-regions (Sowa et al. 2004). The following are the seven levels of classification in hierarchical order: zone, subzone, region, aquatic subregions, EDU, Aquatic Ecological Systems (**AES**), and Valley Segment types (**VST**). The levels of classification are based on biology, zoogeography, taxonomic composition, geology, soils, and groundwater connection. Some levels of the hierarchical system use geology and soils to classify and other levels use biology and taxonomic composition of aquatic communities. Ecological Drainage Units and AES are the two levels of the classification that will be assessed in detail for this study.

2.3.1 Ecological Drainage Unit

The EDU is level five of the classification hierarchy and is based on geographical variation of the taxonomic composition of the level 4 subregions. An EDU is a region in which aquatic biological communities and habitat conditions can be expected to be similar. Table 1 compares the land cover percentages from the Central Plains/Osage/South Grand EDU, Little Drywood Creek biological criteria reference station watershed, and the Little Osage River sampling stations upstream of the sampling locations. Land cover data were derived from Thematic Mapper satellite data from 2000 to 2004 for the entire EDU and from the 2001 national land cover database for the sampling station watersheds. Generally, land use at the Little Osage River sampling stations was slightly lower for percent crops and slightly higher for percent grassland/pasture compared to Little Drywood Creek and the entire Central Plains/Osage/South Grand EDU.

2.3.2 Aquatic Ecological Systems

Aquatic Ecological Systems are level six of the classification hierarchy and classify aquatic systems into AES types based on geology, soils, landform, and groundwater influence. The Little Osage River is located in the South Deepwater AES type. The South Deepwater Creek AES type is made of relatively flat to rolling plains with soil textures primarily made up of silt loams with very slow to moderate infiltration rates and local relief that is usually less than 100 feet. This AES type historically was made up of oak hickory forest and prairie (Sowa and Diamond 2006).

Table 1
Percent Land Cover

Land Cover	Urban	Crops	Grassland	Forest	Wetland
Central Plains/Osage/South Grand EDU	3	28	44	14	5
Little Drywood Creek #1	4	26	49	19	1
Little Osage River #1	5	23	52	16	3
Little Osage River #2	5	20	55	18	2
Little Osage River #3	5	19	49	19	1

2.4 Stream Habitat Assessment

A standardized assessment procedure was followed as described for glide/pool habitat in the Stream Habitat Assessment Project Procedure (**SHAPP**) (MDNR 2010b). The habitat assessment was conducted on all stations during October of 2008.

2.5 Biological Assessment

Biological assessments consisted of macroinvertebrate collection and physicochemical sampling for two sample periods.

2.5.1 Macroinvertebrate Collection and Analysis

A standardized macroinvertebrate sample collection and analysis procedure was followed as described in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**) (2010c) for glide/pool (**GP**) streams. Three standard habitats, depositional substrate in non-flowing water (**NF**), large woody debris (**SG**), and root mat, (**RM**) were collected at the sampling stations.

Macroinvertebrate data were analyzed using two methods. The first analysis was calculating the Macroinvertebrate Stream Condition Index (**MSCI**) using the biological criteria for perennial/wadeable streams from the Central Plains/Osage/South Grand EDU using the four general biological metrics found in the SMSBPP (MDNR 2010c). The four general biological metrics used and found in the SMSBPP are: 1) Taxa Richness (**TR**); 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**); 3) Biotic Index (**BI**); and 4) Shannon Diversity Index (**SDI**). The second analysis was an evaluation of

macroinvertebrate community composition by percent composition of dominant macroinvertebrate groups. Comparisons of the macroinvertebrate community among three Little Osage River test stations were made.

2.6 Physicochemical Data Collection and Analysis

2.6.1 I*n situ* Water Quality Measurements

During each sampling period, *in situ* water quality measurements were collected at all stations. Field measurements included water temperature (°C), dissolved oxygen (mg/L), conductivity (µS/cm), and pH.

2.6.2 Water Chemistry

Grab samples of stream water were collected and returned for analysis to ESP's Chemical Analysis Section. Samples were analyzed for turbidity, chloride, total phosphorus, ammonia-N, nitrate+nitrite-N, and total nitrogen. When collecting water quality samples, procedures were followed as outlined in Field Sheet and Chain of Custody Record, Standard Operating Procedure (**SOP**) MDNR-ESP-002 (MDNR 2010d) and Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations, SOP MDNR-ESP-001 (MDNR 2009). Stream velocity was measured at each station during the survey period using a Marsh-McBirney Flo-Mate™ Model 2000. Discharge was calculated per the methods in the SOP MDNR-ESP-113, Flow Measurement in Open Channels (MDNR 2010e).

2.6.3 Dissolved Oxygen Dataloggers

U.S. EPA, Region 7 deployed dataloggers at three Little Osage River sampling stations in August 2008. Dataloggers were deployed at sampling stations starting at 1:30 PM on August 25 and ending at 1:00 PM on August 28. The dataloggers were programmed to measure and record dissolved oxygen and temperature at 15-minute intervals. For this study, these data were compared to datalogger data that were collected by MDNR Water Quality Monitoring Section staff at four stations on Little Drywood Creek in 2008 for the Ecological and Water Resources and Assessment Project (**EWRAP**).

2.7 Data Analysis and Quality Control

The physicochemical data were examined by analyte to identify stations that had violations of the Missouri Water Quality Standards (MDNR 2010a). Sampling stations that had water chemistry values that were outside the water quality standards will be discussed and possible influences will be identified.

3.0 Results

3.1 Stream Habitat Assessment

Habitat assessment scores and physical characteristics for the Little Osage River test stations and the Little Drywood Creek biological criteria reference reach station are shown in Tables 2 and 3. Habitat data were collected in October 2008, with Carl Wakefield and Brandy Bergthold performing the scoring. SHAPP guidance states that

test stations with habitat scores at least 75 percent of reference/control station scores should support a similar biological community. The stream habitat total scores indicated that the Little Osage River test stations should support a similar macroinvertebrate community compared to Little Drywood Creek since the scores were greater than 75 percent of the Little Drywood Creek habitat score.

Most of the habitat metrics in the SHAPP at the Little Osage River test stations had values and scores that were very similar to the Little Drywood Creek biological criteria reference station. Two of the metrics, epifaunal substrate and vegetative protection, were very low at all or most of the stations including Little Drywood Creek, giving some indication that habitat could affect the macroinvertebrate community. But benthic sediment deposition, which can negatively affect the macroinvertebrate community when found at high levels, was very low at all of the sampling stations. Bank stability was good for most stations, except the left bank at Little Osage River #2 and the Little Drywood Creek reference station, which both scored in the marginal category. Riparian zone was also good for most of the stations, except for both riparian zones at Little Osage River #3 and the left bank riparian zone at Little Osage River #2, which scored in the marginal category.

Table 2
Predominant Category Habitat Values, Category Habitat Scores, and Total Habitat Scores from Stream Habitat Assessments for the Little Osage River Test Stations and the Little Drywood Creek Biological Criteria Reference Station

	Little Osage River #1	**Little Osage River #2**	**Little Osage River #3**	**Little Drywood Creek #1**
Sample Date	10/07/2008	10/08/2008	10/07/2008	10/08/2008
Stream Habitat Parameters				
Epifaunal Substrate/Available Cover	III (8)	III (7)	II(11)	III (10)
Pool Substrate Characterization	II (15)	II (15)	II (15)	II (15)
Pool Variability	II (15)	II (14)	II (14)	II (13)
Sediment Deposition	I (16)	I (16)	I (16)	I (18))
Channel Flow Status	II (14)	II (14)	II (14)	II (13)
Channel Alteration	I (20)	I (20)	I (20)	I (20)
Channel Sinuosity	III (7)	III (7)	III (6)	III (7)
Bank Stability – Left Bank	I (10)	III (4)	I (9)	III (5)
Bank Stability – Right Bank	II (8)	I (9)	II (7)	I (9)
Vegetative Protection – Left Bank	IV (0)	IV (0)	IV (0)	IV (0)
Vegetative Protection – Right Bank	IV (0)	IV (0)	IV (0)	IV (0)
Riparian Zone Width – Left Bank	I (10)	III (3)	III (3)	I (9)
Riparian Zone Width – Right Bank	I (10)	I (10)	III (5)	I (10)
Total Habitat Score	133	119	120	129

Habitat parameter categories range from I to IV with category I = optimal, category II = suboptimal, category III = marginal, and category IV = poor. Habitat parameter scores are listed in parentheses and range from 0 to 20 except for vegetative protection and riparian zone categories which range from 0 to 10.

Table 3
Physical Characteristics of the Little Osage River Bioassessment Sampling Reaches Based on Values from the MoRAP Valley Segment Types (VST) Geographic Information Systems (**GIS**) Layer and Field Measurements Collected as Part of the Stream Habitat Assessment

	L. Osage River #1	L. Osage River #2	L. Osage River #3	L. Drywood Creek #1
Watershed Area (mi^2)	490	414	384	123
Strahler Order	4	4	4	4
Link Magnitude	279	245	226	62
Average Stream Width (feet)	51.8	42.4	57.3	37.6
Stream Gradient (feet/mile)	0.65	0.79	1.38	1.79
Relative Gradient	Low	Low	Low	Low
Sinuosity (mile/mile)	1.94	1.49	1.90	2.13
Temperature Regime	Warm	Warm	Warm	Warm
Stream Size	Small River	Small River	Small River	Small River
Flow Regime	Permanent	Permanent	Permanent	Permanent
Geology	Alluvium	Alluvium	Alluvium	Limestone

3.2 Macroinvertebrate Biological Assessment

3.2.1 Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP)

Macroinvertebrate Stream Condition Index (MSCI) scores were calculated at the Little Osage River test stations using the perennial/wadeable biological criteria for the Central Plains/Osage/South Grand EDU. The MSCI scores for the fall 2008 sampling season are shown in Table 4 and in Table 5 for the spring 2010 sampling season. All three Little Osage River test stations had fully supporting MSCI scores of 20 during the fall 2008 and spring 2010 sampling seasons. Taxa richness, EPTT, and SDI values were much higher and BI was much lower during both sampling seasons at all three Little Osage River test stations compared to the biological criteria for those metrics.

Table 4
Fall 2008 Central Plains/Osage/South Grand EDU Perennial/Wadeable Biological Criteria, Biological Support Categories, and Macroinvertebrate Stream Condition Index (MSCI) Scores at the Little Osage River Test Stations

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	**Support**
L. Osage River #1	0804086	71	12	7.30	3.15	20	F
L. Osage River #2	0804087	76	16	7.20	3.33	20	F
L. Osage River #3	0804085	69	12	7.10	3.06	20	F
Metric Score=5	If	>55	>6	<7.70	>2.87	20-16	**F**ull
Metric Score=3	If	55-27	6-3	7.70-8.90	2.87-1.43	14-10	**P**artial
Metric Score=1	If	<27	<3	>8.90	<1.43	8-4	**N**on

MSCI Scoring Table (in light gray) developed from BIOREF stream samples (n=15); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index

Table 5
Spring 2010 Central Plains/Osage/South Grand EDU Perennial/Wadeable Biological Criteria, Biological Support Categories, and Macroinvertebrate Stream Condition Index (MSCI) Scores at the Little Osage River Test Stations

Stream and Station Number	Sample No.	TR	EPTT	BI	SDI	MSCI	**Support**
L. Osage River #1	1004005	65	12	6.5	3.31	20	F
L. Osage River #2	1004003	55	9	6.7	3.04	20	F
L. Osage River #3	1004004	70	14	6.7	3.18	20	F
Metric Score=5	If	>50	>8	<7.40	>2.53	20-16	**F**ull
Metric Score=3	If	50-25	8-4	7.40-8.70	2.53-1.27	14-10	**P**artial
Metric Score=1	If	<25	<4	>8.70	<1.27	8-4	**N**on

MSCI Scoring Table (in light gray) developed from BIOREF stream samples (n=12); TR=Taxa Richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index

3.2.2 Macroinvertebrate Percent and Community Composition

The percent composition of EPTT, sensitive taxa based on the biotic index, functional feeding groups (**FFG**), functional habitat groups (**FHG**), and the five dominant macroinvertebrate families and taxa at each station are presented in Tables 6 through 9. Values in the tables in bold type represent the five dominant macroinvertebrate families and taxa for each station.

The Little Osage River macroinvertebrate samples were made up of individuals and taxa that had biotic index values that were primarily in the moderately tolerant (5.0 - 7.5) to tolerant (>7.5) range (Tables 6 through 9). During the fall 2008 sampling season, the Little Osage River samples generally had more macroinvertebrates with biotic index values between 5.0 and 7.5 and fewer macroinvertebrates with biotic index values greater than 7.5 compared to reference conditions (Table 6). Macroinvertebrates with biotic index values between 5.0 and 7.5 made up at least 60 percent of the Little Osage River samples compared to about 32 percent for reference conditions. Taxa with biotic index values >7.5 were much less abundant at the Little Osage River test stations than reference conditions, ranging from about 27 percent to 34 percent at the test stations compared to 61 percent for reference conditions. All of the Little Osage River test stations had fewer taxa with biotic index values below 5.0 than reference conditions, ranging from about 3 percent to 5 percent, compared to about 7 percent for reference conditions.

Gatherer-collectors were the most common FFG with values very similar to biological criteria reference streams for the Central Plains/Osage/South Grand EDU. Scrapers were fairly high at test stations #2 and #3, with values a little higher compared to biological criteria data. Filterers and predators were fairly high at station #1 with values a little higher than the biological criteria data, but the values for these FFG were slightly lower than reference conditions at the other two test stations. Shredders were a little higher at test station #1 than other test stations, but all of the values were below reference conditions. Clingers were the most abundant FHG and values at all of the test stations were much higher than reference conditions. Climbers made up a large portion of the samples from the test stations with values from test stations #1 and #2 being much higher than at test station #3 and a little higher than reference conditions. Sprawlers were fairly abundant at the test stations, but were very similar to the biological criteria data. Burrowers were much lower at all of the test stations compared to reference conditions.

Chironomidae was the most abundant family found in the fall 2008 Little Osage River macroinvertebrate samples and was much more abundant at station #1 than the other two sampling stations (Table 7). Chironomid taxa common in samples were *Tanytarsus* at all sampling stations, *Polypedilum halterale* group and *Polypedilum illinoense* group at station #1, and *Thienemannimyia* group and *Phaenopsectra* at station #3. Other macroinvertebrate taxa that were common in all or most samples included the coenagrionid damselfly *Argia*, tubificid worms, pisidiid clams, the heptageniid mayfly *Stenacron*, and the riffle beetle *Dubiraphia*. The biotic index values for these taxa were

in the middle to high range, indicating that these organisms were fairly to highly tolerant of poorer water quality conditions.

During the spring 2010 sampling season, a smaller proportion of the Little Osage River macroinvertebrate samples were made up of taxa with biotic index values between 5.0 and 7.5 and a larger proportion of samples were made up of taxa with biotic index values between 2.5 and 5.0 compared to the fall 2008 sampling season (Table 8). Macroinvertebrates with biotic index values between 5.0 to 7.5 made up about 44 to 48 percent of the Little Osage River samples compared to 39 percent for reference conditions. Taxa with biotic index values >7.5 made up about 31 to 37 percent of Little Osage River samples compared to 49 percent for reference stations. Compared to reference conditions, each of the Little Osage River test stations had a higher percentage of samples made up of macroinvertebrates with biotic index values below 5.0. Whereas biotic index values below 5.0 were about 12 percent in reference samples, Little Osage River samples ranged from about 19 to 22 percent. The majority of taxa in Little Osage River and reference samples that had biotic index values below 5.0 were included in the 2.5 to 5.0 range; however, only about 2 to 4 percent had biotic index values below 2.5.

Gatherer-collectors were the most common FFG, making up over 50 percent of organisms in the samples, which was very similar to biological criteria streams for the Central Plains/Osage/South Grand EDU. Scrapers were fairly high at the Little Osage River test stations, ranging from 8 to 15 percent of the samples. These values were similar to or slightly lower than reference conditions. Predator abundance was slightly higher than reference conditions, ranging from about 9 to 12 percent of the samples. Filterers made up from 7 to 14 percent of the samples, but were higher than reference conditions only at test station #1. Although shredders were fairly abundant in the samples, they were much lower than reference condition values. Clingers were the most abundant FHG, making up over 40 percent of the samples, which was much higher than reference conditions. Climbers were the second most abundant FHG, making up from 15 to 17 percent of the samples, which was much more abundant than reference conditions. Sprawlers were fairly common in all of the samples, but were present in much lower abundance than reference conditions. Swimmers made up at least 10 percent of the samples, which was much more abundant than reference conditions. Burrowers were present in low numbers compared to reference conditions, ranging from 4 to 8 percent of the samples.

Chironomidae was the most abundant family found in the spring 2010 Little Osage River macroinvertebrate samples and was much more abundant at station #1 than the other two sampling stations (Table 9). *Tanytarsus* and *Polypedilum illinoense* group were the two most abundant chironomid taxa found in the Little Osage River samples. Percent EPTT was high in the samples and was represented primarily by the baetid mayfly *Acerpenna* and the heptageniid mayfly *Stenacron*. Tubificid worms were common, making up about 10 to 18 percent of the samples. Other taxonomic groups that were abundant were the black fly *Simulium* at test station #1 and elmid riffle beetles at the other two test stations.

Table 6
Biological Metric Values for Sensitive Taxa, Functional Feeding Groups (FFG), and Functional Habitat Groups (FHG) at the Little Osage River Test Stations and the Biological Criteria Reference Samples, Fall 2008

Variable-Station	**Biocriteria Reference Data**	**L. Osage River #1**	**L. Osage River #2**	**L. Osage River #3**
Sample Number		0804086	0804087	0804085
Sensitive Taxa				
% Biotic Index >9	20.75	17.69	14.86	16.36
% Biotic Index 7.5-9.0	40.12	16.15	18.01	10.23
% Biotic Index 5.0-7.5	31.97	62.88	62.20	69.86
% Biotic Index 2.5-5.0	1.57	2.76	3.74	2.69
% Biotic Index < 2.5	5.59	0.51	1.18	0.86
FFG Metrics				
% Filterers	13.54	19.78	12.69	10.88
% Gatherer-Collectors	40.82	41.73	43.72	45.21
% Parasites	2.45	0.95	0.67	1.17
% Piercers	3.10	6.36	3.22	4.60
% Predators	13.13	15.39	9.96	9.52
% Scrapers	14.93	5.59	17.67	21.30
% Shredders	11.06	9.03	6.80	4.99
FHG Metrics				
% Burrowers	17.47	5.16	5.08	5.71
% Clingers	26.93	37.20	39.90	45.84
% Climbers	12.40	30.89	26.24	19.49
% Divers	0.09	0.07	0.07	0
% Skaters	0.09	0.07	0.14	0.08
% Sprawlers	13.51	13.71	13.05	10.52
% Swimmers	6.68	1.29	3.85	4.00

Table 7
Percent EPT, Dominant Macroinvertebrate Families, and Taxa at the Little Osage River Test Stations and Biological Criteria Reference Samples, Fall 2008 Sampling Season

Variable-Station	**Biotic Index**	**Biocriteria Data**	**L. Osage River #1**	**L. Osage River #2**	**L. Osage River #3**
Sample Number			0804086	0804087	0804085
EPT Metrics					
% EPT		20.8 ± 0.9	5.99	25.1	34.0
% Ephemeroptera		19.2 ± 0.8	4.8	23.3	31.4
% Plecoptera		0	0	0	0
% Trichoptera		1.6 ± 0.2	1.1	1.8	2.6
Percent Dominant Families					
Chironomidae		**37.0 ± 0.7**	**65.4**	**40.8**	**36.1**
Coenagrionidae		2.8 ± 0.2	**9.7**	**7.1**	**4.3**
Tubificidae		**9.0 ± 0.4**	**8.2**	**8.1**	**12.9**
Pisidiidae		1.0 ± 0.1	**3.3**	5.0	1.8
Heptageniidae		**8.3 ± 0.5**	**2.7**	**15.6**	**24.4**
Hyalellidae		**4.4 ± 0.3**	0.7	1.3	0.2
Elmidae		**4.4 ± 0.5**	0.9	**8.3**	**4.4**
Caenidae		**5.9 ± 0.5**	0.8	3.7	2.7
Percent Dominant Taxa					
Tanytarsus	6.7	4.0 ± 0.3	**23.3**	**13.2**	**10.8**
Argia	8.7	2.3 ± 0.2	**9.7**	**6.6**	3.8
Tubificidae	9.2	**7.1 ± 0.3**	**7.5**	**6.8**	**12.3**
Polypedilum halterale grp.	7.2	0.1 ± 0.0	**5.1**	1.0	1.5
Polypedilum illinoense grp.	9.2	1.2 ± 0.1	**5.1**	1.3	1.4
Stenacron	7.1	**7.9 ± 0.5**	2.7	**15.3**	**24.4**
Dubiraphia	6.4	4.4 ± 0.5	0.4	**6.9**	3.3
Thienemannimyia grp.	6	1.9 ± 0.1	2.3	2.4	**4.4**
Phaenopsectra	6.2	3.2 ± 0.3	0	0.9	**4.1**
Glyptotendipes	8.5	**7.6 ± 0.6**	0	0.1	0.1
Dicrotendipes	7.9	**6.1 ± 0.3**	0.5	0.5	0.2
Caenis latipennis	7.6	**5.9 ± 0.5**	0.2	1.9	1.3

Biocriteria data values are average percent ± standard deviation.

Table 8
Biological Metric Values for Sensitive Taxa, Functional Feeding Groups (FFG), and Functional Habitat Groups (FHG) at the Little Osage River Test Stations and the Biological Criteria Reference Samples, Spring 2010

Variable-Station	**Biocriteria Reference Data**	**L. Osage River #1**	**L. Osage River #2**	**L. Osage River #3**
Sample Number		1004005	1004003	1004004
Sensitive Taxa				
% Biotic Index >9.0	25.64	14.42	14.63	23.99
% Biotic Index 7.5-9.0	23.63	16.35	20.34	13.38
% Biotic Index 5-7.5	38.64	47.56	44.91	43.83
% Biotic Index 2.5-5.0	9.47	19.64	18.29	14.65
% Biotic Index < 2.5	2.62	2.04	1.83	4.15
FFG Metrics				
% Filterers	7.64	13.80	8.72	7.20
% Gatherer-Collectors	52.57	51.68	56.15	55.40
% Parasites	1.21	0.37	0.08	0.08
% Piercers	1.29	4.85	2.65	4.37
% Predators	6.37	12.08	9.42	9.80
% Scrapers	13.72	8.20	14.88	13.49
% Shredders	16.35	7.98	5.69	7.89
FHG Metrics				
% Burrowers	20.99	7.92	5.83	4.30
% Clingers	27.28	43.36	46.63	42.07
% Climbers	5.24	17.44	15.27	15.68
% Divers	0.14	0	0	0
% Skaters	0	0	0	0
% Sprawlers	20.67	11.36	6.90	11.30
% Swimmers	1.92	10.00	11.08	9.95

Table 9
Percent EPT, Dominant Macroinvertebrate Families, and Taxa at the Little Osage River Test Stations and Biological Criteria Reference Samples, Spring 2010 Sampling Season

Variable-Station	Biotic Index	Biocriteria Data	L. Osage River #1	L. Osage River #2	L. Osage River #3
Sample Number			1004005	1004003	1004004
EPT Metrics					
% EPT		10.3 ± 0.8	27.1	40.5	35.6
% Ephemeroptera		7.9 ± 0.6	24.1	36.0	29.8
% Plecoptera		1.3 ± 0.6	1.6	1.6	2.9
% Trichoptera		1.1 ± 0.1	1.5	2.9	3.0
Percent Dominant Families					
Chironomidae		**54.4 ± 2.5**	**49.9**	**30.5**	**34.6**
Tubificidae		**10.3 ± 0.5**	**9.9**	**11.8**	**18.0**
Asellidae		**6.6 ± 1.1**	0.2	**4.2**	2.0
Simuliidae		**5.0 ± 0.5**	**3.1**	0	0
Caenidae		**3.2 ± 0.3**	0.6	1.0	1.5
Baetidae		1.4 ± 0.4	**13.8**	**15.4**	**13.3**
Heptageniidae		2.2 ± 0.2	**9.3**	**19.2**	**14.9**
Elmidae		0.4 ± 0.0	2.8	**4.2**	**4.4**
Percent Dominant Taxa					
Cricotopus/Orthocladius grp.	6.5	**21.8 ± 1.5**	0.6	0.1	0.1
Hydrobaenus	9.6	**10.9 ± 0.9**	0.1	0	0
Lirceus	7.7	**6.6 ± 1.1**	0.2	**4.2**	2.0
Tubificidae	9.2	**6.0 ± 0.3**	**8.2**	**11.0**	**15.7**
Simulium	4.4	**4.8 ± 0.5**	3.0	0	0
Acerpenna	3.7	1.4 ± 0.4	**12.8**	**15.4**	**13.0**
Tanytarsus	6.7	1.3 ± 0.1	**11.8**	**6.5**	**7.2**
Stenacron	7.1	2.0 ± 0.2	**9.0**	**18.1**	**12.1**
Polypedilum illinoense grp.	9.2	2.5 ± 0.7	**4.8**	2.6	**6.7**

Biocriteria data values are average percent ± standard deviation.

3.3 Physicochemical Data

Water samples and field measurements were collected during the fall 2008 and spring 2010 macroinvertebrate sampling periods. Physicochemical results are arranged to demonstrate trends of certain variables that may identify a source for effects at the Little Osage River test stations. Results can be found in Table 10 for the fall 2008 sampling season and Table 11 for the spring 2010 sampling season. Results presented in the following subsections include discharge, turbidity, and total phosphorus by season.

3.3.1 Stream Discharge

Discharge was very similar among Little Osage River sampling stations during the fall 2008 sampling season, ranging from 22.7 cfs at station #2 to 23.1 cfs at station #1.

Discharge was much higher during the spring 2010 sampling season, ranging from 67.9 cfs at station #3 to 127 cfs at station #1. Discharge was not measured at station #1 because a suitable location to measure discharge could not be found. The discharge value for this station was obtained from USGS gaging station number 06917060 located just downstream of the sampling station at Horton, Missouri.

Table 10
Physicochemical Variables at the Little Osage River Bioassessment Study Sampling Stations, Fall 2008

	Little Osage River #1	Little Osage River #2	Little Osage River #3
Invertebrate Sample Number	0804086	0804087	0804085
Physicochemical Sample Number	0810048	0810049	0810047
Sample Date	10/07/2008	10/08/2008	10/07/2008
Sample Time	1435	1035	1130
Ammonia	0.03*	0.03*	0.03*
Chloride	6.92	6.99	7.06
Dissolved Oxygen	5.93	7.01	5.03
Discharge (cfs)	23.1	22.7	22.8
pH (Units)	7.86	7.58	7.80
Conductivity (µmhos/cm)	587	673	643
Temperature (°C)	17.6	15.0	19.3
Turbidity (NTU)	4.02	2.09	4.05
Nitrate + Nitrite	0.07	0.07	0.10
Total Nitrogen	0.36	0.34	0.36
Total Phosphorus	0.06	0.04**	0.04**

*Below detectable limits
**Estimated value, detected below Practical Quantitation Limit
Units mg/L unless otherwise noted.

Table 11
Physicochemical Variables at the Little Osage River Bioassessment Study Sampling Stations, Spring 2010

	Little Osage River #1	Little Osage River #2	Little Osage River #3
Invertebrate Sample Number	1004005	1004003	1004005
Physicochemical Sample Number	1000918	1000916	1000917
Sample Date	04/15/2010	04/15/2010	04/15/2010
Sample Time	1615	1100	1340
Ammonia	0.09	0.15	0.13
Chloride	6.01	5.63	5.71
Dissolved Oxygen	8.26	7.59	7.15
Discharge (cfs)	127*	70.1	67.9
pH (Units)	8.2	7.7	8.2
Conductivity (µmhos/cm)	534	556	554
Temperature (°C)	20.6	18.9	19.9
Turbidity (NTU)	**44.5**	**38.4**	**25.9**
Nitrate + Nitrite	0.01**	0.01***	0.04****
Total Nitrogen	0.44	0.45	0.43
Total Phosphorus	0.09	**0.11**	**0.10**

*Discharge was not measured, value obtained from USGS gaging station number 06917060 located at Horton, Missouri
**Below detectable limits
***Below detectable limits and analysis was performed past the holding time
****Estimated value, detected below Practical Quantitation Limit
Units mg/L unless otherwise noted. Values in bold are elevated compared to U.S. EPA recommended reference condition values

3.3.2 Turbidity

Turbidity was low during the fall 2008 sampling season, ranging from 2.09 Nephelometric Turbidity Units (**NTU**) at station #2 to 4.05 NTU at station #3. Turbidity was much higher during the spring 2010 sampling season, ranging from 25.9 NTU at station #3 to 44.5 NTU at station #1. The spring 2010 values were elevated compared to

the U.S. EPA recommended reference value of 15.5 NTU for the level III Central Irregular Plains ecoregion (U.S. EPA 2000).

3.3.3 Total Phosphorus

Total phosphorus concentrations were low during the fall 2008 sampling season, ranging from <0.04 mg/L at stations #2 and #3 to 0.06 mg/L at station #1. Total phosphorus was slightly higher during the spring 2010 sampling season, ranging from 0.09 mg/L at station #1 to 0.11 mg/L at station #2. The spring 2010 concentrations were slightly elevated at stations #2 and #3 compared to the U.S. EPA recommended reference value of 0.0925 mg/L for the level III Central Irregular Plains ecoregion.

3.4 Dissolved Oxygen Dataloggers

Results from the U.S. EPA Region 7 dataloggers are shown in Figures 3-5. Dataloggers were deployed at or near the Little Osage River macroinvertebrate sampling stations from August 25-28, 2008 (Figure 2).

Dissolved oxygen values at U.S. EPA datalogger station #1 ranged from 4.36 to 5.64 mg/L and were below the water quality standard of 5 mg/L (MDNR 2010a) 56.5 percent of the time (Figure 3). At station #2, dissolved oxygen ranged from 3.87 to 5.52 mg/L and was below 5 mg/L 75.6 percent of the time (Figure 4). Dissolved oxygen ranged from 3.09 to 4.36 mg/L at station #3 with all of the values below 5 mg/L (Figure 5).

3.5 Little Drywood Creek Datalogger Data

Dissolved oxygen dataloggers were deployed by MDNR Water Quality Monitoring Section staff at four sampling stations within the biological criteria reference reach of Little Drywood Creek during the summer and fall months of 2008. These data were collected on behalf of the Environmental Resources Coalition (ERC) for part of an EWRAP study. Sampling station location, sampling dates, and dissolved oxygen results are presented in Table 12.

Dissolved oxygen concentrations tended to be lower at the most upstream station (Little Drywood Creek #1), with more readings below the water quality standard than the remaining stations. Whereas approximately 46 percent of Little Drywood Creek #1 dissolved oxygen readings were below the water quality standard, only about 6 to 7 percent were below 5 mg/L at stations #2 and #3. Violations were more common, however, at station #5, which had 22 percent of readings below the standard. Stations #2 and #3 were located in the upper part of the biological criteria reference reach, whereas station #5 was located toward the downstream end of the reference reach.

Figure 3
U.S. EPA Dissolved Oxygen Datalogger Readings
Little Osage River Station #1
August 25-28, 2008

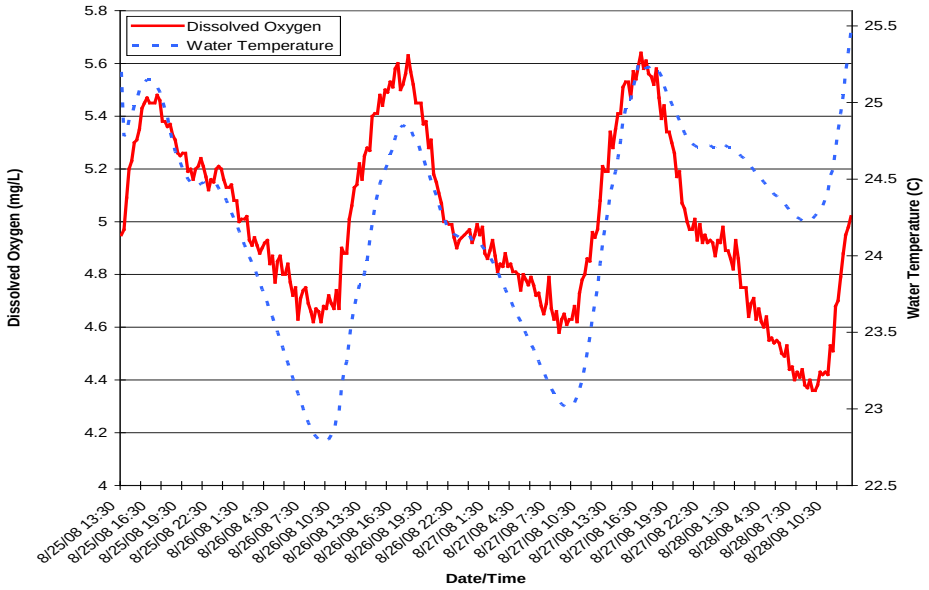


Figure 4
U.S. EPA Dissolved Oxygen Datalogger Readings
Little Osage River Station #2
August 25-28, 2008

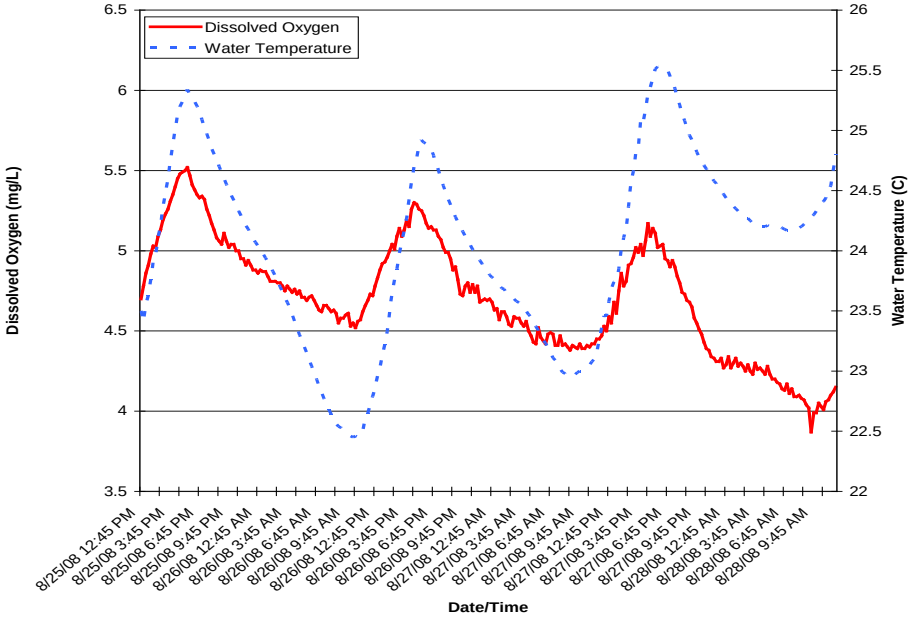


Figure 5
U.S. EPA Dissolved Oxygen Datalogger Readings
Little Osage River Station #3
August 25-28, 2008

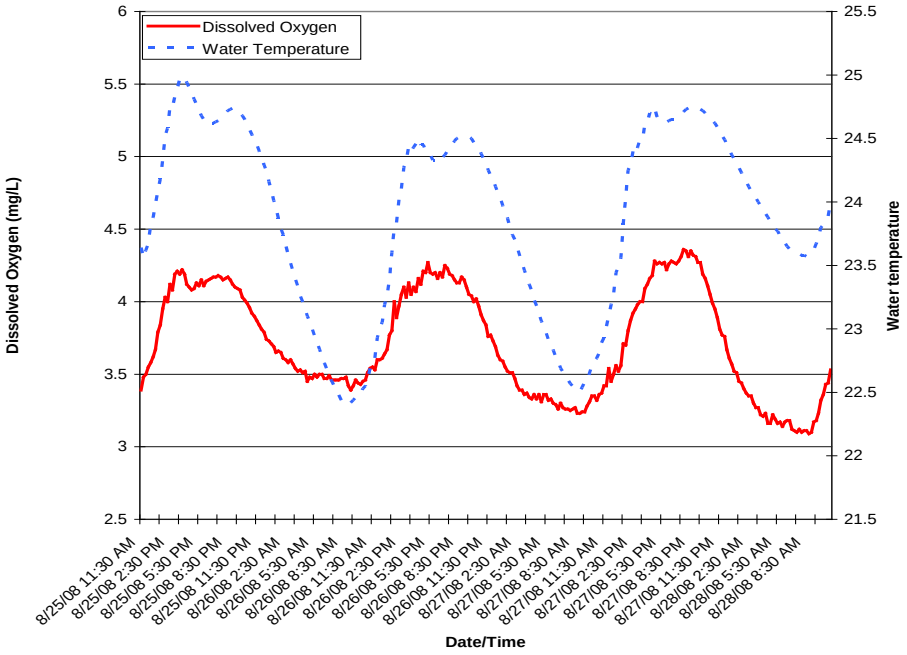


Table 12
Dissolved Oxygen (D.O.) Datalogger Data Collected at Little Drywood Creek in 2008 for the EWRAP Study

Sample Station	L. Drywood Cr. #1	L. Drywood Cr. #2	L. Drywood Cr. #3	L. Drywood Cr. #5
Station Location Description	Northwest of Zodiac Road	Near Zebulon Road	South of Highway N	South of Stokes Road
UTM Easting	377693	377004	377053	377040
UTM Northing	4168144	4169298	4173201	4181802
Sampling Dates	07/14/08-08/27/08	07/14/08-07/22/08 07/29/08-09/28/08	07/14/08-07/27/08	07/29/08-08/26/08
# of D.O. Readings	4210	5785	1419	2551
Average D.O.	4.92	6.52	5.98	5.48
D.O. Range	3.32-7.53	2.36-8.61	4.26-7.84	4.18-6.96
% D.O. Readings <5.0 mg/L	46.2	5.6	6.3	22.0

4.0 Discussion

4.1 Possible Dissolved Oxygen Effects

The U.S. EPA datalogger data collected from August 25-28, 2008 found that dissolved oxygen levels were below the water quality standard of 5 mg/L 56.5 percent of the time at Little Osage River station #1, 75.6 percent of the time at station #2, and 100 percent of the time at station #3 (Figures 3-5). A previous Little Osage River bioassessment study (MDNR 2007) using a dissolved oxygen datalogger found that all of the dissolved oxygen values collected at test station #3 from July 25-28, 2006 were below the water quality standard. Other streams in the Central Plains/Osage/South Grand EDU, including the biological criteria reference stream Little Drywood Creek, sometimes have dissolved oxygen levels below the water quality standard during low flow periods in the summer and fall months. The results from the EWRAP study showed that in 2008 Little Drywood Creek had some values below the water quality standard but were generally higher and violated the water quality standards less often compared to the dissolved oxygen data collected at the Little Osage River sampling stations.

Little Osage River MSCI scores were fully supporting during both sample seasons and suggest an unimpaired aquatic community that is comparable to the Central Plains/Osage/South Grand EDU biocriteria reference data. Although biotic index individual metric scores were fully supporting at all Little Osage River stations during both seasons, there were subtle differences in the composition of this metric that may be related to dissolved oxygen concentrations. The majority of samples during both seasons were made up of moderately tolerant (BI 5.0-7.5) to tolerant (BI>7.5) macroinvertebrates,

but the overall biotic index values were lower during the spring 2010 sampling season when dissolved oxygen concentrations were well above minimum standards. The percentage of moderately sensitive taxa (i.e., BI<5.0) was considerably higher in spring compared to the fall sample season, which contributed to the lower biotic index values for those samples. In addition, the percentage of moderately sensitive taxa among Little Osage River samples was higher than that of the reference data. The intolerant baetid mayfly *Acerpenna* seemed to be the primary macroinvertebrate taxon that led to lower biotic index values during the spring 2010 sampling season. *Acerpenna*, which has a biotic index value of 3.7, was found in low abundance during the fall 2008 sampling season, ranging from 0.4 percent of the sample at test station #1 to 1.1 percent at test station #3. But during the spring 2010 sampling season, *Acerpenna* was one of the most abundant taxa found in the Little Osage River samples, ranging from 12.8 percent at test station #1 to 15.4 percent at test station #2.

4.2 MSCI and Macroinvertebrate Community Structure

The low dissolved oxygen levels found in the Little Osage River during the summer of 2008 did not seem to have negatively affected the majority of biological metrics that make up the MSCI. The metric that was an exception, fall 2008 biotic index, was discussed in the previous section. Taxa richness, EPTT, and SDI values were much higher and BI was much lower than reference conditions during both sampling seasons at the three Little Osage River test stations. The biotic index results also indicated that the samples collected during the spring 2010 sampling season were made up of more macroinvertebrates that were intolerant of poor water quality conditions than the macroinvertebrates collected during the fall 2008 sampling season. In addition to dissolved oxygen, stream size may also be a factor influencing the Little Osage River biological metrics. The three Little Osage River sampling stations are much larger than the Central Plains/Osage/South Grand EDU biological criteria reference streams (Table 3). The River Continuum Concept proposed by Vannote et al. (1980) predicted that macroinvertebrate taxa richness should increase from headwater streams to mid-order streams and reach its maximum because environmental heterogeneity are greatest in mid-order streams. Habitat and environmental conditions that factor into this increased abundance for mid-order streams include flow regime, temperature, food quality and quantity, and substrate composition. A study of first through fourth order South Carolina upper coastal plains streams found that TR and EPT increased and BI decreased with increasing stream width (Paller et al. 2006). The results of the South Carolina study and the stream size for the Central Plains/Osage/South Grand EDU biological criteria reference streams suggest that stream size may help explain the higher biological metric values at the Little Osage River test stations compared to the reference streams.

Gatherer-collectors were the most abundant FFG during both sampling seasons in Little Osage River and were present in similar abundance compared to reference conditions. Two FHGs, clingers and climbers, were present in greater abundance in Little Osage River samples compared to reference conditions. These results were inconclusive as they relate to water quality conditions. The predicted response of gatherer-collectors to

increasing water quality perturbation was variable according to Barbour et al. (1999), but Rabeni et al. (2005) found that this FFG was tolerant of high benthic sediment levels. Clingers, on the other hand, are considered to be sensitive to water quality perturbations including high benthic sediment levels (Barbour et al. 1999, Rabeni et al. 2005). Climbers were reported by Rabeni et al. (2005) to be tolerant of high benthic sediment levels, but the predicted response to water quality perturbations was not listed by Barbour et al. (1999).

The Tanytarsini chironomid *Tanytarsus* and tubificid worms were both abundant at all Little Osage River test stations during the fall 2008 sampling season. *Tanytarsus* ranged from about 11 percent of the sample at station #3 to 23 percent at station #1, which was much higher than the reference condition value of 4 percent. The state of Ohio currently uses the biological metric Percent Tanytarsini (the taxonomic tribe in which *Tanytarsus* is classified) as one of the metrics for the state's Invertebrate Community Index (Deshon 1995). In Ohio, Tanytarsini taxa are often the predominant midge group at reference sites. Chironomids in Tanytarsini generally are considered intermediate in pollution tolerance and can decline or disappear under moderate pollution stress. Other taxa common in the fall 2008 samples at one or more of the test stations was the damselfly *Argia* at stations #1 and #2, chironomids *Polypedilum halterale* group and *Polypedilum illinoense* group at station #1, the heptageniid mayfly *Stenacron* at stations #2 and #3, the riffle beetle *Dubiraphia* at station #2, and chironomids *Thienemannimyia* group and *Phaenopsectra* at station #3. *Stenacron* was the only common EPTT in the samples and was very abundant at stations #2 and #3. The biotic index for the most common taxa found in the Little Osage River samples ranged from 6.0 for *Thienemannimyia* group to 9.2 for tubificid worms and *Polypedilum illinoense* group.

During the spring 2010 sampling season, tubificid worms, the baetid mayfly *Acerpenna*, the Tanytarsini chironomid *Tanytarsus*, and the heptageniid mayfly *Stenacron* were common at all three Little Osage River sampling stations. All of these taxa except for tubificid worms were much more common in the Little Osage River samples than reference conditions. Other taxa common at one or more of the test stations was the isopod *Lirceus* at station #2 and the chironomid *Polypedilum illinoense* group at stations #1 and #3. The biotic index for the most common taxa found in the Little Osage River samples ranged from 3.7 for *Acerpenna* to 9.2 for tubificid worms and *Polypedilum illinoense* group.

5.0 Conclusions

Despite the low dissolved oxygen levels observed by the U.S. EPA during the summer of 2008, each of the three Little Osage River sample stations achieved the highest possible MSCI score during both the fall 2008 and spring 2010 sampling seasons. Dissolved oxygen concentrations may have had some effect on biotic index values during the fall 2008 sampling season, but any effects were insufficient to reduce the score for this metric. Biotic index values were much higher at the Little Osage River sampling stations during the fall 2008 sampling season than the spring 2010 sampling season. The spring

2010 samples were made up of more macroinvertebrates that were intolerant of poor water quality conditions than the macroinvertebrates found in the fall 2008 samples. Taxa richness, EPTT, and SDI values were much higher and BI was much lower than reference conditions during both sampling seasons at the Little Osage River test stations. Stream size possibly could explain the high biological metric scores since the Little Osage River sample reach was much larger than the Central Plains/Osage/South Grand EDU biological criteria reference streams.

The first null hypothesis stated that the macroinvertebrate community will not differ between longitudinally separate reaches of the Little Osage River. The second null hypothesis stated that the macroinvertebrate community in the Little Osage River will not differ from the glide/pool biological criteria for the Central Plains/Osage/South Grand EDU. These two null hypotheses were accepted based on the results of the MSCI scores.

The third hypothesis stated that stream habitat assessment scores will not differ between longitudinally separate reaches of the Little Osage River. The fourth hypothesis stated stream habitat assessment scores in the Little Osage River will not differ from Little Drywood Creek, a glide/pool biological criteria reference stream in the Central Plains/Osage/South Grand EDU. The third and fourth null hypotheses were accepted based on the stream habitat scores. Stream habitat assessment results indicated that all of the sampling stations should have macroinvertebrate habitat comparable to reference conditions.

The fifth hypothesis stated that physicochemical water quality in the Little Osage River will meet the Water Quality Standards of Missouri (MDNR 2010a). The sixth hypothesis stated physicochemical water quality will not differ between longitudinally separate reaches of the Little Osage River. The fifth hypothesis was rejected, but the sixth null hypothesis was accepted based on the U.S. EPA dissolved oxygen datalogger data. The U.S. EPA results showed that dissolved oxygen levels were below the water quality standard of 5 mg/L a substantial amount of the time during the period in which the dataloggers were deployed. The percent of time that dissolved oxygen was below 5 mg/L ranged from about 56 percent at station #1 to 100 percent at station #3.

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Appendix A

Little Osage River Macroinvertebrate Taxa Lists

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [0804085], Station #3, Sample Date: 10/7/2008 11:30:00 AM
NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	16	2	
AMPHIPODA			
Crangonyx		5	
Hyalella azteca		2	
COLEOPTERA			
Dubiraphia	11	19	1
Lioporeus		1	6
Macronychus glabratus		1	1
Neoporus		1	
Stenelmis		3	5
DECAPODA			
Orconectes immunis		1	
Orconectes virilis		-99	
Palaemonetes kadiakensis		-99	
DIPTERA			
Ablabesmyia	5	4	
Anopheles		1	
Ceratopogoninae	5	2	
Chironomidae	2	1	
Chironomus	2		
Cladotanytarsus	1		1
Corynoneura		12	
Cricotopus bicinctus		1	1
Cricotopus/Orthocladius	2	2	16
Cryptochironomus	5		
Dicrotendipes			2
Glyptotendipes			1
Harnischia	1		
Hemerodromia			2
Hydrobaenus			6
Labrundinia	2	5	2
Microtendipes	1		1
Paratanytarsus		1	
Phaenopsectra	5	2	31
Polypedilum fallax grp			1
Polypedilum halterale grp	7	2	5
Polypedilum illinoense grp	1	10	2
Procladius	3		
Rheotanytarsus	2	6	3

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ORDER: TAXA	NF	RM	SG
Stelechomyia			3
Stempellina	1	1	
Stenochironomus	1		20
Tanytarsus	35	27	38
Thienemanniella	1	2	8
Thienemannimyia grp.	1	2	38
EPHEMEROPTERA			
Acerpenna	1	3	6
Apobaetis	1		
Caenis latipennis	7	5	
Caenis punctata	2	11	
Callibaetis		2	
Hexagenia	3	2	
Leptophlebiidae	1	3	2
Procloeon	12	1	3
Stenacron	76	87	64
HEMIPTERA			
Corixidae	2		
Microvelia		1	
Neoplea		1	
ISOPODA			
Lirceus		3	
LIMNOPHILA			
Menetus		1	
MEGALOPTERA			
Sialis			1
ODONATA			
Argia	8	24	3
Enallagma		5	
Gomphus	-99	1	
Libellula		2	
Macromia	1		
TRICHOPTERA			
Cheumatopsyche			20
Hydroptila		1	
Triaenodes		3	
TUBIFICIDA			
Branchiura sowerbyi	5		
Enchytraeidae	3		
Quistradrilus multisetosus		1	

Aquid Invertebrate Database Bench Sheet Report
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ORDER: TAXA	NF	RM	SG
Tubificidae	92	10	12
VENEROIDA			
Pisidiidae	10		7

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [0804086], Station #1, Sample Date: 10/7/2008 2:35:00 PM
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ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	9		6
AMPHIPODA			
Hyalella azteca		7	
ARHYNCHOBDELLIDA			
Erpobdellidae		-99	
COLEOPTERA			
Berosus	1		
Dubiraphia	4		
Macronychus glabratus		1	
Neoporus		1	
Stenelmis	1	3	
DECAPODA			
Orconectes virilis		2	
Palaemonetes kadiakensis		7	
DIPTERA			
Ablabesmyia	21	10	3
Anopheles		1	
Ceratopogoninae	7		2
Chironomus	2		
Cladotanytarsus	4		4
Corynoneura	5	4	
Cricotopus bicinctus		3	2
Cricotopus/Orthocladius		3	3
Cryptochironomus	9		3
Dicrotendipes			5
Diptera	1		
Forcipomyiinae			1
Gonomyia		1	
Harnischia	1		
Hemerodromia			7
Hydrobaenus	1	4	33
Labrundinia	18	11	11
Nanocladius	3	4	5
Parakiefferiella			1
Paralauterborniella	12	1	
Paratanytarsus		1	
Polypedilum halterale grp	23	2	25
Polypedilum illinoense grp	8	40	2
Polypedilum scalaenum grp	8	1	5

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [0804086], Station #1, Sample Date: 10/7/2008 2:35:00 PM
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ORDER: TAXA	NF	RM	SG
Procladius		1	
Pseudochironomus			1
Pseudosmittia			1
Rheotanytarsus		15	14
Stelechomyia	1		8
Stempellina	1		
Stempellinella		1	
Stenochironomus	4		7
Tanypus	1		
Tanytarsus	28	93	107
Thienemanniella	2	3	7
Thienemannimyia grp.	4	7	11
Tribelos	12	2	8
EPHEMEROPTERA			
Acerpenna		3	1
Baetis			3
Caenis latipennis		2	
Caenis punctata	3	2	1
Callibaetis		1	
Leptophlebiidae		1	
Procloeon	1	1	1
Stenacron	14	6	6
Tricorythodes		1	
HEMIPTERA			
Corixidae	2		
Rheumatobates		1	
LIMNOPHILA			
Ancylidae		1	
Physella	1	1	
ODONATA			
Argia	19	72	4
RHYNCHOBDELLIDA			
Glossiphoniidae		1	
TRICHOPTERA			
Cheumatopsyche		6	1
Nectopsyche	1	2	
Oecetis		1	
TRICLADIDA			
Planariidae		1	
TUBIFICIDA			

Aquid Invertebrate Database Bench Sheet Report
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ORDER: TAXA	NF	RM	SG
Branchiura sowerbyi	5		1
Enchytraeidae	3		
Quistradrilus multisetosus		1	
Tubificidae	63	10	
VENEROIDA			
Pisidiidae	27	3	2

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [0804087], Station #2, Sample Date: 10/8/2008 10:35:00 AM
NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	7	1	3
AMPHIPODA			
Crangonyx		-99	
Hyalella azteca		13	
COLEOPTERA			
Dubiraphia	9	60	1
Dytiscidae		1	
Macronychus glabratus		1	2
Scirtidae		2	
Stenelmis	6	5	
DECAPODA			
Orconectes virilis	-99		-99
Palaemonetes kadiakensis	-99	3	
DIPTERA			
Ablabesmyia	7	1	2
Ceratopogoninae	16		2
Chironomus			5
Cladotanytarsus	2		3
Corynoneura	2	12	5
Cricotopus bicinctus	11	6	2
Cricotopus/Orthocladius	6	4	6
Cryptochironomus	3		
Culicidae		1	
Dicrotendipes			5
Diptera		1	
Ephydridae	1		
Glyptotendipes	1		
Harnischia	3		
Hemerodromia			2
Hydrobaenus	10	11	27
Labrundinia	7	3	1
Larsia		1	
Nanocladius		3	
Paracladopelma	3		
Paralauterborniella			1
Paratanytarsus		1	1
Phaenopsectra		2	7
Polypedilum	1		
Polypedilum halterale grp	8	1	1

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [0804087], Station #2, Sample Date: 10/8/2008 10:35:00 AM
NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence

ORDER: TAXA	NF	RM	SG
Polypedilum illinoense grp	2	7	4
Polypedilum scalaenum grp		1	18
Procladius	1		1
Pseudochironomus			1
Rheocricotopus		1	
Rheotanytarsus	4	1	
Stelechomyia	1		1
Stempellina		1	1
Stenochironomus	2		7
Tanytarsus	34	40	60
Thienemanniella	1	1	8
Thienemannimyia grp.	5		19
Tribelos			11
Zavreliella	1		1
Zavrelimyia	4		
EPHEMEROPTERA			
Acerpenna		2	
Apobaetis	7		
Brachycercus	1		
Caenis latipennis	1	16	2
Caenis punctata		18	
Callibaetis		3	
Heptageniidae	2		
Hexagenia limbata	2		
Leptophlebiidae	2	6	1
Procloeon	5	2	7
Stenacron	35	57	63
Stenonema femoratum		1	
Tricorythodes	1	3	
HEMIPTERA			
Corixidae	1		
Neoplea		1	
Rheumatobates		2	
ODONATA			
Argia	2	53	12
Enallagma		4	
Ischnura		1	
Nasiaeschna pentacantha		1	
TRICHOPTERA			
Cheumatopsyche	1		
Nectopsyche		10	

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ORDER: TAXA	NF	RM	SG
Triaenodes		7	
TUBIFICIDA			
Branchiura sowerbyi	13		
Tubificidae	67		2
VENEROIDA			
Pisidiidae	48	2	1

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [1004003], Station #2, Sample Date: 4/15/2010 11:30:00 AM
NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	1		
AMPHIPODA			
Crangonyx	1	8	
Hyalella azteca		7	
COLEOPTERA			
Dubiraphia	7	13	1
Macronychus glabratus		1	5
Stenelmis	6	2	2
DECAPODA			
Orconectes immunis		-99	-99
Palaemonetes kadiakensis		-99	
DIPTERA			
Ablabesmyia	9	1	9
Ceratopogoninae	9		3
Chironomidae	2		6
Chironomus	2		
Cladotanytarsus	7		3
Cricotopus/Orthocladius			1
Cryptochironomus	3		2
Cryptotendipes	1		
Dicrotendipes			5
Diptera	1		
Harnischia	3	1	
Hemerodromia	1	2	14
Nilotanypus		1	
Paracladopelma	1		1
Parakiefferiella			10
Paralauterborniella	18		4
Paratendipes	2		
Polypedilum halterale grp	6		
Polypedilum illinoense grp	2	20	1
Polypedilum scalaenum grp	3	2	31
Procladius	1		
Rheotanytarsus		5	7
Stelechomyia			5
Stempellina	1		
Stenochironomus			5
Tanytarsus	18	28	11
Thienemanniella	1	1	

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ORDER: TAXA	NF	RM	SG
Thienemannimyia grp.		6	9
Tribelos	6	2	4
EPHEMEROPTERA			
Acerpenna		110	25
Caenis latipennis	1	8	
Hexagenia limbata		1	1
Stenacron	3	61	94
Stenonema femoratum		7	3
Tricorythodes		1	
ISOPODA			
Lirceus	3	24	10
ODONATA			
Argia	3	18	5
Enallagma	1	1	
Nasiaeschna pentacantha		1	
PLECOPTERA			
Perlesta	1	11	2
TRICHOPTERA			
Cheumatopsyche		16	9
Oecetis		-99	
TUBIFICIDA			
Branchiura sowerbyi	4		
Enchytraeidae	1		
Limnodrilus claparedianus	1		
Limnodrilus hoffmeisteri	2		
Tubificidae	95	1	

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [1004004], Station #3, Sample Date: 4/15/2010 2:00:00 PM
NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence

ORDER: TAXA	NF	RM	SG
AMPHIPODA			
Crangonyx		7	
Hyalella azteca		4	
ARHYNCHOBDELLIDA			
Erpobdellidae	-99		
COLEOPTERA			
Dineutus		1	
Dubiraphia	5	3	1
Dytiscidae	1		
Scirtidae		1	
Stenelmis	14	10	5
DECAPODA			
Orconectes virilis		-99	
Palaemonetes kadiakensis	-99		
DIPTERA			
Ablabesmyia	19	4	3
Ceratopogoninae	8	1	1
Chironomidae	4	1	
Chironomus	2		
Cladotanytarsus	7		2
Corynoneura		1	
Cricotopus/Orthocladius			1
Cryptochironomus	7		2
Cryptotendipes	2		
Dicrotendipes		1	1
Hemerodromia	1		4
Labrundinia		1	
Nanocladius		3	
Nilotanypus	1	4	1
Ormosia			1
Paracladopelma			1
Parakiefferiella	2	2	4
Paralauterborniella	8		
Paratanytarsus		1	
Paratendipes	1		
Polypedilum convictum		7	
Polypedilum fallax grp			4
Polypedilum illinoense grp	5	50	3
Polypedilum scalaenum grp	5	3	7
Procladius	2		

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [1004004], Station #3, Sample Date: 4/15/2010 2:00:00 PM
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ORDER: TAXA	NF	RM	SG
Rheotanytarsus		8	
Stelechomyia			1
Stempellinella	2		
Stenochironomus	2		2
Tanytarsus	3	42	17
Thienemanniella	2	8	1
Thienemannimyia grp.	5	16	8
Tribelos	9		2
EPHEMEROPTERA			
Acentrella			2
Acerpenna	5	96	12
Caenis latipennis	6	5	1
Caenis punctata		1	
Leptophlebiidae		1	
Leucrocuta	6		2
Stenacron	24	29	52
Stenonema femoratum	5	1	10
ISOPODA			
Lirceus	2	9	6
ODONATA			
Argia	2	8	4
Calopteryx		1	
Nasiaeschna pentacantha		-99	
PLECOPTERA			
Isoperla			1
Perlesta	2	18	4
RHYNCHOBDELLIDA			
Piscicolidae	1		
TRICHOPTERA			
Cheumatopsyche		9	4
Hydroptila		1	
Ironoquia		9	1
Pycnopsyche		1	1
TUBIFICIDA			
Aulodrilus	3		
Branchiura sowerbyi	8	1	
Enchytraeidae		1	
Ilyodrilus templetoni	2		
Limnodrilus claparedianus	2		1
Limnodrilus hoffmeisteri	2		
Quistradrilus multisetosus	1		

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ORDER: TAXA	NF	RM	SG
Tubificidae	126		10

Aquid Invertebrate Database Bench Sheet Report
Little Osage R [1004005], Station #1, Sample Date: 4/15/2010 4:30:00 PM
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ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	2		3
AMPHIPODA			
Crangonyx		4	
Hyalella azteca		9	
COLEOPTERA			
Dubiraphia	1	2	
Macronychus glabratus	1		5
Scirtidae		2	
Stenelmis	5	2	8
Uvarus			1
DECAPODA			
Palaemonetes kadiakensis		-99	-99
DIPTERA			
Ablabesmyia	10	10	3
Ceratopogoninae	7	2	3
Chironomidae	6	15	8
Cladotanytarsus	10		
Corynoneura			1
Cricotopus bicinctus		2	1
Cricotopus/Orthocladius	1		4
Cryptochironomus	9		
Cryptotendipes	1		
Dicrotendipes	1		7
Diplocladius		1	
Eukiefferiella			1
Hemerodromia			12
Hydrobaenus			1
Labrundinia			1
Nanocladius	3		1
Nilothauma		1	
Parakiefferiella	2	1	21
Paralauterborniella	14	7	1
Paratanytarsus		5	
Polypedilum aviceps		2	1
Polypedilum halterale grp	5		
Polypedilum illinoense grp	1	41	
Polypedilum scalaenum grp	9	1	25
Pseudosmittia			4
Rheotanytarsus	2	12	13

Aquid Invertebrate Database Bench Sheet Report
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ORDER: TAXA	NF	RM	SG
Simuliidae			1
Simulium	1	14	11
Stempellina	2		
Stenochironomus	2		6
Stictochironomus	1		
Tanytarsus	19	51	34
Thienemanniella		6	
Thienemannimyia grp.	4	16	19
Tribelos	8		7
EPHEMEROPTERA			
Acentrella			9
Acerpenna	7	62	44
Caenis latipennis		5	
Leptophlebiidae		2	
Stenacron	28	9	42
Stenonema femoratum	2		1
Tricorythodes			1
ISOPODA			
Lirceus		2	
ODONATA			
Argia	5	6	4
Gomphus	-99		
PLECOPTERA			
Perlesta		5	9
RHYNCHOBDELLIDA			
Glossiphoniidae	1	-99	
TRICHOPTERA			
Cheumatopsyche		4	3
Hydroptila		1	
Ironoquia		3	1
Oecetis		1	
TUBIFICIDA			
Branchiura sowerbyi	3		
Limnodrilus claparedianus	9		
Limnodrilus hoffmeisteri	3		
Tubificidae	65	2	5
VENEROIDA			
Pisidiidae	1		